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Distribution and Parasitism of Root-knot Nematodes on Citrus[1]

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INTRODUCTION: It is useful for Florida citrus growers to be aware of nematode pests of citrus occurring in other parts of the world because these pests could be introduced accidentally into Florida. This circular provides information on the distribution, biology, and parasitic habits of root-knot nematode pests of citrus in the Western and Eastern hemispheres.

In the Western Hemisphere, citrus (*Citrus* spp.) are among the few crops which are spared from root-knot nematode infections. In North, Central and South America, and the Mediterranean basin, root-knot nematode infections on citrus are rare and of negligible economic importance. Five species of root-knot nematodes [*Meloidogyne arenaria* (Neal, 1889) Chitwood 1949, *M. exigua* Goeldi, 1892, *M. hapla* Chitwood, 1949, *M. incognita* (Kofoid & White, 1910) Chitwood, 1949, and *M. javanica* (Treub, 1885) Chitwood, 1949] are reported from citrus in these geographical areas (Table 1). Although reproduction on citrus roots has been observed for some populations of *M. exigua* and *M. javanica*, the majority of the populations of the root-knot nematode species listed above are not able to complete their life cycle on citrus. Root-knot nematode juveniles of these species can sometimes penetrate and cause swelling of citrus roots. However, they do not induce formation of fully developed giant cells, which are essential for juvenile maturation and egg production (Inserra *et al.* 1978; Orion and Cohn 1975).

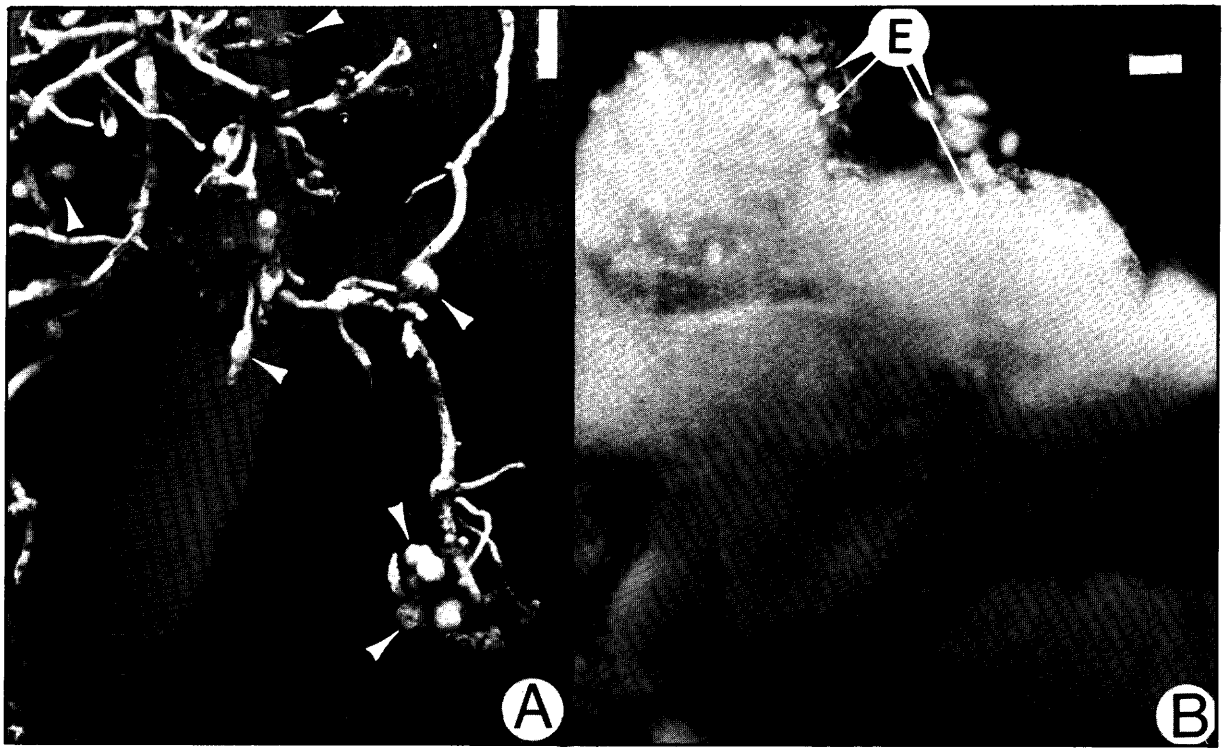

Fig. 1. Satsuma roots infected by *Meloidogyne citri*. A) Galls (arrows) along the axes and at the tips of the fibrous roots. B) Gall with two large egg masses. E = eggs. Scale bars = 4 mm in A and 132 µm in B.

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Table 1. Root-knot nematode species detected on citrus in the Western Hemisphere.

Geographical areas and citrus rootstocks	*Ma*[2/]	*Me*	*Mh*	*Mi*	*Mj*	Reference
Guadeloupe (French Indies)						
Citrus (*Citrus* sp.)		+[1/]				Scotto La Massese 1969
Israel						
'Cleopatra' mandarin (*Citrus reticulata* Blanco)					*	Orion and Cohn 1975
Lime [*C. aurantifolia* (Christm.) Swingle]					+	Minz 1956
Italy						
Sour orange (*C. aurantium* L.)				*	*	Accorti and Ambrogioni 1976
Trifoliate orange [*Poncirus trifoliata* (L.) Raf.]					*	Inserra *et al.* 1978
'Troyer' citrange (*X Citroncirus webberi* J. Ingram & H.E. Moore)					*	Accorti and Ambrogioni 1976; Inserra *et al.* 1978
Surinam						
Citrus (*Citrus* sp.)		+				Den Ouden 1965
USA (California)						
'Troyer' citrange			*	*	* +	Van Gundy *et al.* 1959 (*Mh, Mi, Mj*); Gill 1971 (*Mj*)
Sour orange			-	*	- +	Van Gundy *et al.* 1959 (*Mh, Mi, Mj*); Gill 1971 (*Mj*)
Sweet orange [*Citrus sinensis* (L.) Osbeck]			-	-	-	Van Gundy *et al.* 1959
'Cleopatra' mandarin					+	Gill 1971
USA (Florida)						
Bittersweet orange (*Citrus aurantium* L.)	+					Neal 1889
Sour orange	+					Neal 1889

[1/]Symbols indicate: - = no infection: * = infection without reproduction; + = infection and reproduction.
[2/]*Ma* = *Meloidogyne arenaria*; *Me* = *M. exigua*; *Mh* = *M. hapla; Mi* = *M. incognita*; and *Mj* = *M. javanica*.

Among the species listed in Table 1, *M. javanica* is the most common root-knot nematode occurring on citrus in the Western Hemisphere; however, only two populations of this species have been observed to reproduce on citrus. They have been reported in California (Gill 1971) and in Israel (Minz 1956) (Table 1). The spread of these populations in citrus orchards was contained in both California and Israel.

Reports of infection and reproduction by root-knot nematodes on citrus are more common in the Eastern Hemisphere than in the Western Hemisphere. With the exception of *M. incognita*, root-knot nematode species occurring on citrus in this part of the world differ from those reported in the Western Hemisphere. These species are: the Asiatic pyroid citrus nema, which is an undescribed species; *M. citri* Zhang, Gao & Weng, 1990; *M . donghaiensis* Zheng, Lin & Zheng, 1990, *M. fujianensis* Pan, 1985, *M. indica* Whitehead, 1968; *M. jiangyangensis* Yang, Hu, Chen & Zhu, 1990; *M. kongi* Yang, Wang & Feng, 1988; *M. mingnanica* Zhang, 1993; and *M. oteifae* Elmiligy, 1968. Citrus hosts and countries of these species are listed in Table 2. The majority of root-knot species parasitizing citrus in the Eastern Hemisphere have been described in the last 12 years. Biology of these root-knot nematodes is not well known and needs further study.

Table. 2. Root-knot nematode species reported on citrus in the Eastern Hemisphere.

Geographical areas and citrus rootstock	**APCN**[2/]	***Mc***	***Md***	***Mf***	***Mi***	***Mid***	***Mjg***	***Mk***	***Mm***	***Mo***	**Reference**
Australia											
Sweet orange [*C. sinensis* (L.) Osbeck]					+[1/]						Colbran 1958
China (Mainland)											
Citrus (*Citrus* sp.)								+			Yang *et al.* 1988
Mandarin orange (*C. reticulata* Blanco)			+	+			+			+	Zheng *et al.* 1990 (*Md*); Pan 1984 (*Mo*); Pan 1985 (*Mf*); Yang *et al.* 1990 (*Mjg*)
Satsuma [*C. unshiu* (Mack.) Marc]		+							+		Zhang *et al.* 1990 (*Mc*); Zhang 1993 (*Mm*)
Taiwan											
Mandarin orange	+										Chitwood and Toung 1960b
Pummelo [*C. maxima* (Burm.) Merr.]	+										Chitwood and Toung 1960b
Sour orange (*C. aurantium* L.)	+										Chitwood and Toung 1960b
India											
Citrus (*Citrus* sp.)						+					Whitehead 1968
Sweet orange	+										Chitwood and Toung 1960b

[1/]Symbol + indicates nematode infection and reproduction

[2/]APCN = Asiatic pyroid citrus nema; *Mc = Meloidogyne citri*; *Md = M. donghaiensis*; *Mf = M. fujianensis*; *Mi = M. incognita*; *Mid = M. indica*; *Mjg = M. jiangyangensis*; *Mk = M. kongi; Mm = M. mingnanica*; *Mo = M. oteifae.*

ROOT-KNOT NEMATODES OCCURRING ON CITRUS IN AUSTRALIA, INDIA AND TAIWAN: Before 1984, only three species of root-knot nematodes were reported parasitizing citrus in the Far East. They were *M. incognita* in Australia; the Asiatic pyroid citrus nema in India and Taiwan; and *M. indica* on citrus in India (Table 2). The taxonomic status of the Asiatic pyroid citrus nema remains undefined. Chitwood and Toung (1960a) considered this species similar to *M. africana* Whitehead 1968, but they did not complete the study of its morphology. In addition to the citrus species listed in Table 2, the Asiatic pyroid citrus nema is able to infect corn (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench] and sweet potato (*Ipomea batatas* L.) (Chitwood and Toung 1960b). The description of *M. indica* from citrus in India (Whitehead 1968) may suggest that the pyroid citrus nema and *M. indica* are the same species since they share a common host, *C. sinensis* (Table 2). However, the biological information on the Asiatic pyroid citrus nema and *M. indica* is scant and limited to a few citrus hosts listed in Table 2. So far, *M. indica* has been reported only in India. In Australia, *M incognita* has been detected only once (1958) on *C. sinensis* (Table 2).

ROOT-KNOT NEMATODES REPORTED ON CITRUS IN MAINLAND CHINA: All reports relative to root-knot nematodes on citrus after 1984 are from China. *Meloidogyne oteifae* was the first species detected on citrus in mainland China (Table 2). *Meloidogyne fujianensis* was described as a new species from citrus, in 1985. It was found on mandarin in Fujian

Province (Table 2). More than 30 percent of citrus surveyed in Nanjing district was found infected with this nematode (Pan 1985). In 1988, *M. kongi* was detected in Guangxi Province on unidentified citrus (Table 2). In 1990, three more species were reported from China: *M. jiangyangensis* on mandarin orange in Sichuan Province; *M. citri* on satsuma in Fujian Province; and *M donghaiensis* on mandarin in Fujian Province (Table 2). In 1993, another species was found on satsuma in southern Fujian and described as *M. mingnanica* (Table 2). In recent studies, this species and *M. citri* were able to infect *Poncirus trifoliata*, but failed to infect sour orange *(C. aurantium* L.*)* and tangerine *(C. reticulata* Blanco) (Zhang and Xu 1994). However, information relative to the biology, host range, ecology, parasitism and damaging effects of these root-knot nematodes is unknown. It is not known if these root-knot nematodes (*e.g.*, Asiatic pyroid citrus nema) are able to infect herbaceous hosts other than citrus. Information on the host range of these species is very important to prevent possible spread to other plants such as weeds.

The histopathology induced by *M. citri* has been studied on infected satsuma roots (Vovlas *et al.* 1996). Satsuma roots infected by *M. citri* show swollen root tips and axes (Fig. 1A). Nematode egg masses, containing 168-450 eggs, are visible on the surface of the galls (Fig. 1B). Multiple infection sites are common, resulting in galls containing more than one female. The host response caused by *M. citri* on satsuma does not differ from that reported for other root-knot nematodes on other plants. Formation of specialized cells (giant cells) in the stele, disruption of the vascular system, and hyperplasia of the vascular parenchyma are the most common anatomical alterations observed in infected satsuma roots (Fig. 2).

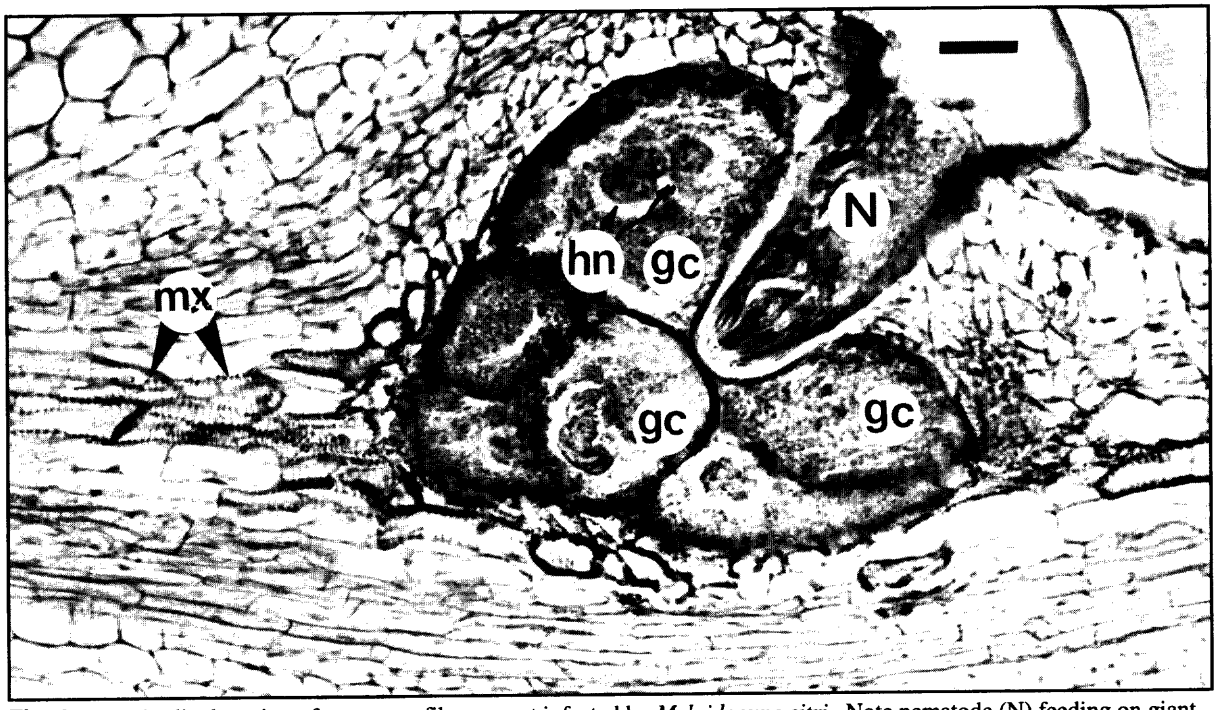

Fig. 2. Longitudinal section of a satsuma fibrous root infected by *Meloidogyne citri.* Note nematode (N) feeding on giant cells (gc), which have distrupted metaxylem elements (mx) compromising the function of the vascular system. hn = hypertrophied nuclei. Scale bar = 70 µm.

SURVEY AND DETECTION: Root symptoms induced on citrus by the root-knot nematodes listed in Table 2 are similar to those described for *M. citri.* Since these pests cause obvious galls in citrus fibrous roots, nematode infection can be detected by visual observations of swollen tips or axes (Fig 1A) which indicate potential root-knot nematode infection. During routine surveys for nematodes in citrus orchards, abnormally swollen fibrous roots should be placed in plastic bags with soil from the rhizosphere and submitted to the Nematology Section of DPI for nematological analysis. Microscopic examination of the roots is necessary to separate galls induced by root-knot nematodes from tip swellings caused by sting and dagger nematode feeding. The occurrence of root-knot nematodes on weeds is common in Florida citrus groves. Soil samples from these groves are positive for root-knot nematodes because they originate from weed hosts. Careful examination and separation of the roots in the samples provides certainty of the origin of nematode infestation. Root-knot nematode surveys based only on nematological analysis of soil provide only an indication of nematode presence, but not of hosts.

CONCLUSIONS: With the exception of *M. incognita*, the root-knot nematode species occurring on citrus in the Far East (Table 2) are not reported in Florida or elsewhere in the Western Hemisphere. It is known that infection and development of root-knot nematode species are favored by coarse-textured soils which are low in organic matter—much like the sandy soils of the Florida ridge. Florida citrus growers should be aware that these pests could be introduced into Florida on citrus or on plants other than citrus. Strict implementation of nematode import quarantines and adherence to the nematode certification program for citrus nurseries is the most effective method to prevent the spread of these pests into citrus-growing areas of the state.

LITERATURE CITED:

Accorti, M., and L. Ambrogioni. 1976. Root-knot nematode (*Meloidogyne* sp.) infections on *Citrus* spp. and *Myoporum* sp. in Italy. Redia 59: 323-330.

Chitwood, B.G., and M.C. Toung. 1960a. *Meloidogyne* from Taiwan and New Delhi. Phytopathology 50: 631-632.

Chitwood, B.G., and M.C. Toung. 1960b. Host-parasite interactions of the Asiatic pyroid citrus nema. Plant Disease Reporter 44: 848-854.

Colbran, R.C. 1958. Studies of plant and soil nematodes. Queensland Journal of Agricultural Science 15: 101-135.

Den Ouden, H. 1965. An infestation on citrus in Surinam caused by *Meloidogyne exigua*. Surinaamse Landbouw 13: 34.

Gill, G.S. 1971. Occurrence and reproduction of *Meloidogyne javanica* on three species of *Citrus* in California. Plant Disease Reporter 55: 607-608.

Inserra, R.N., G. Perrotta, N. Vovlas, and A. Catara. 1978. Reaction of citrus rootstocks to *Meloidogyne javanica*. Journal of Nematology 10: 181-184.

Minz, G. 1956. The root-knot nematode, *Meloidogyne* spp., in Israel. Plant Disease Reporter 40: 798-801.

Neal, J.C. 1889. Root-knot disease of peach, orange, and other plants in Florida, due to the work of *Anguillula.* United States Department of Agriculture, Bureau of Entomology, Bulletin 20. 31 p.

Orion, D., and E. Cohn. 1975. A resistant response of *Citrus* roots to the root-knot nematode *Meloidogyne javanica.* Marcellia 38: 327-328.

Pan, C. 1984. Studies on plant-parasitic nematodes on economically important crops in Fujian. I. Species of root-knot nematodes (*Meloidogyne* spp.) and their host plants. Acta Zoologica Sinica 30: 159-167.

Pan, C.S. 1985. Studies on plant-parasitic nematodes on economically important crops in Fujian. III. Description of *Meloidogyne fujianensis* n.sp. (Nematoda-Meloidogynidae) infecting citrus in Nanjing District. Acta Zoologica Sinica 31: 263-268.

Scotto La Massese, C. 1969. The principal plant nematodes of crops in the French West Indies. pp. 164-183 *In* J.E. Peachey (ed.) Nematodes of tropical crops. Commonwealth Bureau of Helminthology, Technical Communication 40.

Van Gundy, S.D., I. Thomason, and R.L. Rackhman. 1959. The reaction of three *Citrus* spp. to three *Meloidogyne* spp. Plant Disease Reporter 43: 970-971.

Vovlas, N., D. Zhang, and S. Zhang. 1996. Description of the host-parasite relationship of the root-knot nematode *Meloidogyne citri* with *Citrus unshiu.* Programme and abstracts of VIII Congress of International Society of Citriculture (12-17 May, 1966), Sun City, South Africa. (p 156).

Whitehead, A.C. 1968. Taxonomy of *Meloidogyne* (Nematoda-Heteroderidae) with description of four new species. Transactions of the Zoological Society of London 31: 263-401.

Yang, B., K. Hu, H. Chen, and W. Zhu. 1990. A new species of root-knot nematode, *Meloidogyne jiangyangensis* n.sp. parasitizing mandarin orange. Acta Phytopathological Sinica 20: 259-264.

Yang, B., Q. Wang, and R. Feng. 1988. *Meloidogyne kongi* n. sp. (Nematoda: Meloidogynidae) a root-knot nematode parasitizing *Citrus* sp. in Guangxi China. Journal of Guangxi Agricultural College 7 (3): 1-9.

Zhang, S.S. 1993. *Meloidogyne mingnanica* n. sp (Meloidogynidae) parasitizing citrus in China. Journal of Fujian Agricultural University 22: 69-76.

Zhang, S., R. Gao, and Z. Weng. 1990. *Meloidogyne citri* n. sp. (Meloidogynidae) a new root-knot nematode parasitizing citrus in China. Journal of Fujian Agricultural College 19: 305-311.

Zhang, S.S., and M.Y. Xu. 1994. Identification of root-knot nematode in Fujian province and its control. China Citrus 23 (1): 9-11.

Zheng, L., M. Lin, and M.H. Zheng. 1990. Occurrence and identification of a new disease of the citrus, Donghai root-knot nematode *Meloidogyne donghaiensis* sp. nov., in coast sand soil of Fujian in China. Journal of Fujian Academy of Agricultural Sciences 5 (2): 56-63.